A REVIEW ON SOLID STATE NUCLEAR TRACK DETECTOR

[1]LAKSHAY CHAUDHARY, [2]B. S. RAWAT
[1]Scholar, [2]Associate Professor
[1,2]Department of Physics, UCALS, Uttaranchal University, Dehradun, India

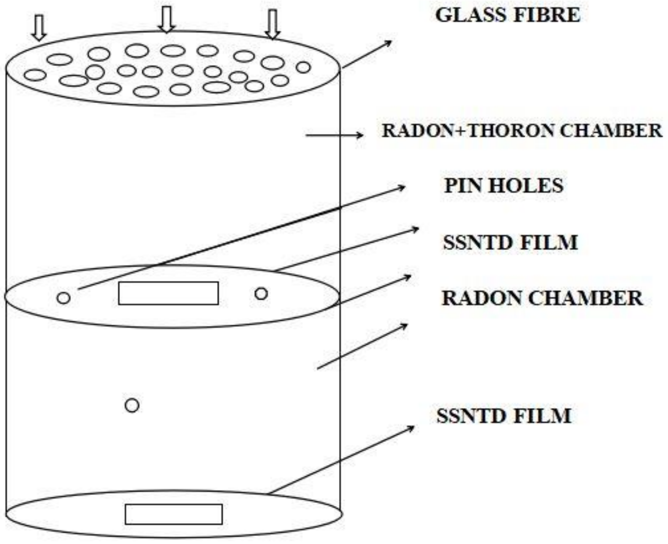
Abstract: Solid State Nuclear Track Detectors (SSNTD) are generally used for the detection of radon (^{222}Rn), thoron (^{220}Rn) and concentrations of progeny commonly. In addition, Etching Process of Solid state Nuclear Track Detectors and Twin Cup Dosimeters has been discussed. In the present study a review on Solid State Nuclear Track Detector (SSNTD) types and comparison among them has been made.

Index Terms: LR 115,CR-39, SSNTD, Radon, Thoron.

I. INTRODUCTION

SSNTDs have a lot of applications in almost all science fields including the fields of chemistry and biology in the last 20 years of Technology of Nuclear Tracks. SSNTD technique has been discovered by D.A. Young in 1958. The non-complexity of the technique is the reason that it is not dependent upon costly electronics, on the one hand, and the availability in essentially background-free situation of a variety of detectors with differing susceptibilities to charged particles, on the other.[1] Because it is easy to handle and available for CR-39, CR-39 offers large properties in alpha particles recording in physics such as health physics, radiation physics, nuclear physics, and archeology. For practical use, CR-39 sample particles have been irradiated at normal incident angle with alpha particulates. The power was between 1.29 and 5.48 MeV. Through observing etch pit, tracks of alpha particles can sufficiently be recognized. Solid State Nuclear Track detectors have huge areas of applications in aspect of technology such as environmental sample radon / thoron estimates and natural radiation dosage and space radiation assessments. On a solid state nuclear track detector's surface, when heavy loaded particles (alpha particulate matter) bombard, they react with the detector material–breaking the molecular bonds of the material from the Solid State Nuclear Track Detector which creates a damaged area along their trail–until they lose all their energy in passage through the detector. These detectors vary in samples because of chemical composition and the process of manufacture and due to the process of chemical etching. [2]

The CR-39 is the most important member and available on a commercial scale of the Solid State Nuclear Track Detector Family. It can detect all alpha energy without any degradation from zero to more than 7.7 MeV. Its other component LR-115 is used in radon / thoron measurements, the LR-115, a sensitive detector of cellulose nitrate, is also popular. It is made of a thick nitrate layer of cellulose on a thick polyester supporter. Solid State Nuclear Track (SSNTD) Detectors are majorly used for long-term measurement of radon and thoron [3]. The detectors reaction depends on a number of physical system-related factors. They come mainly through two processes, namely (i) chemical etching track development and (ii) optical or other conventional track counting techniques. Fleischer et al [4] have recognized the potential for radon measurements with these detectors. The first instruments were proposed as Terradex TRACK ETCH in 1967, and patents were made by Alter and Price in 1968 [5] and Becker's [6] patent disclosure. Microscopes are the optical track measuring tool that is easiest and most widely used. LR 115 is a partially opaque track detector material and tracks are formed through and through holes. The counting tracks process using the spark meter Cross and Tommassino[7] is the most frequently used technique other than the large-scale optical measuring system using LR 115 films. Solid State Nuclear Track Detectors (SSNTDs) [8-9] are both insulated natural and human made artificial solids.When a charged particle which is heavily dosed with ions passes through such isolated solids (detectors having inorganic crystals,plastics and glass insulation in them), it leaves a damage of narrow trail of about 50 Å in diameter along its path. This is called ‘Latent Track’.We use an electron microscope to look because it is impossible to see it with our naked eye.ring At the damage site, the nature of the physical and chemical changes occurs depends on the load (Z) and velocity of the particle ($\beta = \pi/c$, where π represent particle velocity and c represent light velocity), the detector material's chemical structure, as well as environmental conditions such as temperature and pressure. Etching is the process in which under an optical microscope these latent tracks can be made and their size can be maximised with the help of some chemicals such as sodium hydroxide and hydrofluoric acid, CR-39 is a very sensitive detector in use nowadays in place of Cellulose Nitrate which was the first but poor detector used to record tracks of alpha.[10] First detector which was used to record alpha tracks was Cellulose Nitrate. Polycarbonate detectors such as Lexan are usually used to record tracks of fragments of fission. Use of Solid State Nuclear Track detectors in potential applications are increasing quickly. They have been in practice and use in various fields, particularly in the field of nuclear studies and technology.[11] Below are some of the unique and sepcial qualities of these detectors that make them extremely useful for a wide range of studies: [10-12]



(i) They are inexpensive and simple to use.
(ii) The user may choose from between the range of varying sensitivity based detectors to meet the specific needs of the charged particles. This makes them attractive in front of an undesirable background radiation, e.g. alpha radiography calculation of radial burn-up profile of highly irradiated fuel elements to investigate specific, rare and low-cross section events.
(iii) Integration of the detector enables events to accumulate for a larger time. The stored information is kept almost for infinite long time under natural temperature and pressure and other favourable conditions.
(iv) Appropriate for different geometric figures such as 2π, 4π, forward and reverse geometry also.
They can be taken in practice in any almost any size; Because of minute size they are easy handy and available to get used in experimental locations where man could not reach. These features of SSNTDs make it one of its kind among other scientific tools generally available in combination with some ingenuity on the part of the investigator for studies involving ionizing particles.

With the invention of CR39 plastic the relationship of neutron dosimetry has been increased with SSNTD. Its unique features of proton registration, photon insensitivity and tiny size allow it to be applied to neutron dose working in a complex radiation field. For neutron dosimetry, CR-39 can be used for recoil and (n,α) reactions. It is known as one of the best detectors in neutron fields when available tools could not work as expected. CR-39 can be measured as a neutron field that appears in a laser-induced fusion process where fission neutrons are emitted as a single pulse rapidly on a very fast scale, dispersed in a small fuel target. Many types of SSNTD have been made since years for this process. The neutron's equivalent dose is calculated by measurement of track density on the detector's surface caused by fission, scattering (n,α) and other reactions from the heavy charged particle produced by the neutron. Recoil calculation of proton by using CR39 is very common in dosimetry process. New scope of SSNTD will be in the field flux measurements of low neutrons.

Inhalation-related exposure of radon and its fission particles are the top most of the natural radionuclides that humans are exposed to in the general environment. Based on studies epidemiological , the theory has been introduced that the increased indoor radon levels can cause health hazards and can lead to severe health issues such as cancer[13-15]. It is therefore of particular interest to humanity to measure the presence of ^{222}Rn in the environment. ^{222}Rn is a radioactive gas generated by a atom of the ^{238}U series Ra decline. ^{222}Rn spreads through the soil to the environment. Radon concentration and its decay products show large fluctuation depending on building materials, soil, ventilation conditions and wind speed, etc.[16-19].

We know that very well that the radiations emitted from the crust of Earth of the primordial radionuclides are the biggest dealer to the total background exposures of human populations. These include external exposures of gamma and exposures of inhalation, which are roughly equally caused by radon, thoron and their daughter in the surroundings. Evaluation of these exposures of present in different locations of the country provides the necessary data to obtain national averages and distribution of population exposures in nation present in background.[20] Nambi et al. (1986) [21] conducted a survey of external exposures of gamma across the country that made it possible to generate India's gamma exposure map. Sankaran et al. (1986) [22] developed a similar terrestrial radioactivity profile. To get a measurement of total radiation exposures, these data need to be analyse with those of inhalation exposures. Upon this data, the Department of Atomic Energy sponsored countrywide radon mapping programs in India, in which several universities and national institutes participated. There were two parts to this program: (i) Evolution and standardization of passive monitoring devices (depend on SSNTDs) for simultaneous radon, thoron and progeny estimation ; (ii) large-scale installment of such dosimeters and country-wide radon and thoron based line data generation.

II. REVIEW OF LITERATURE

From the paper published on 2009: (SSNTDs), such as LR 115, were generally used for the calculation of radon gas concentrations in diffusion chambers. The active layer removed during chemical etching was found to be highly affected by the presence and amount of stirring for the LR115 SSNTD and thus can not be handled easily.The effective thickness of the active layer removed affect the working of LR 115 detector to the concentration of Radon and Thoron.[23]Radon ^{222}Rn is a gas basically inert having a half-life of approx. 4 days that occurs naturally. It is well beleived that cancer in lungs are caused by short lived progeny of radon. The alpha tracking method is a commonly used method for measuring the concentration of long-term radon gas. If we talk about this process, a solid state nuclear track detector (SSNTD)with the most widely used the LR 115 and CR-39 SSNTDs is placed inside a diffusion chamber. As a gas, radon can irradiate the SSNTD into the chamber of diffusion and latent tracks left. On chemical process of etching, we use optical microscope with the appropriate magnification to view and count tracks. Thoron ^{220}Rn is a 55.6-half-life ^{222}Rn radioisotope. In normal environments, thoron concentration is usually much losser than radon concentration due to its short half-life. However, there are cases where it is not possible to neglect the concentration of thoron gas [24-26]. When using the alpha track method, we measure the track density per unit time on the LR 115 SSNTD. The average concentration of radon or thoron gas is obtained during the exposure period by dividing the density of the track with the sensitivity per unit time. However, it is pre known that for varying active layer thickness of the LR 115 SSNTDs removed, varying densities of track and therefore we will get varying sensitivities. For various active layer thicknesses removed for ^{222}Rn and ^{220}Rn, the sensitivities of the LR 115 SSNTD are determined here.[27-28]

This bonding between the sensitivity and the thickness of active layer removed is linked to the structure of the diffusion chamber and the result of the 218Po deposition diffused in the chamber[29], and the working of the LR 115 detector V (V is the ratio between the track etch velocity V_t and the velocity V_b). In this study it was observed that the sensitive working of the LR SSNTD within a Karlsruhe diffusion chamber were determined for different active layer thicknesses removed for ^{222}Rn and ^{220}Rn, and for chemical etching 10 percent of aqueous NaOH at 60 ° C with magnetic stabilization were used. The depth of the active layer was calculated by the infrarot transmission. Furthermore, the V function of the LR 115 detector [30] has been used to stimulate the bonding between the sensitivity and the size of the layer removed. Therefore, the sensitivities of LR 115 within the diffusion chamber are completely dependent on the actual thickness of the removed active layer.

From the paper, published on 2004: Dosimeters based on twin chamber SSNTDs are used to estimate radon (^{222}Rn), thoron (^{220}Rn) gasses and air concentrations of their daughter. These dosimeters use dual numbers of LR-115 of second type detectors for gas concentration estimates inside each of the two chambers and one more detector for progeny measurements has been placed outside.Etched and counted tracks formed on the detector using spark counting techniques under special conditions. A theory based model was developed to distinguish these detectors reacts to alpha particles of varying energy incidents on the surfaces of detectors at different angels. This involves estimating both bulk etch rates and track etch rates in corporations for the total track formation time required. Using this data,we can measure the area of influence for the given dosimeter geometry.From this area,Calibration factors (CFs) are obtained using the model-calculated detectable tracks.

From the paper which was published on January 2001: The primary source of natural ionizing radiation is α-radioactive noble gas radon (^{222}Rn). Three isotopes of Radon are derived from three radioactive series of nature. Thus, the dominant contributors to the activity are the ^{222}Rn isotopes originating from the ^{238}U series and ^{220}Rn (Thoron) originating from the ^{232}Thorium series. ^{219}Rn (Actinon), which originates from the ^{235}U series, is usually negligible for its contribution to air activity due to its rare occurrence of less than 1 %. ^{219}Rn (Actinon), which originates from the ^{235}U series, is usually negligible for its contribution to air activity due to its rare occurrence of less than 1 %. Radon particles calculations using SSNTDs were used in the pre warnings of earthquake in previous time. [31] and calibration factors were calculated and measured for LR 115 detector material. [32]

The detector materials produced in years 1981, 1994 and February 1999 found a dependency of v_b in the bottom in the CN layer. The rate of bulk etching of each of these detectors can be equals to with the rate of etching process of two constants, that is one present at topmost and one at the bottom. Constant bulk etching rate has been found for each of the detector materials that has been made in 1986 and following years 1988 and 1990.[33]

It is known that, due to the decomposition of the CN due to chemical changes, the LR 115 CN detector commonly lost its efficiency after about 5 years. Materials and resultants from the LR 115 detector should be kept in a light tight container at approximately+ 4 C and radon tight to avoid this ageing effect. Process of ageing is dominated because of a very important factor known as storage detector material. For LR 115 detectors, the following conclusions were drawn: the bulk etching rate of the same batch detectors is same for more than 5 years ; detectors of other batches over the age of 5 stored at + 20C show an odd bulk etching rate behaviour and the calibration factor of different batch detectors stored at + 4C over 5 years is constant.[34]

III. CONCLUSION

From the studies discussed above, it is found that the counting Spark counting for measuring etched tracks in LR 115 films and CR-39 provides close proximity by counting the spark and the tracks calculated by using the microscope between the corrected tracks. A theoretical methodology for calculating track to factors of conversion for radon has been developed,for non active monitoring of these gases, thoron-discriminating dosimeters also known as twin cup used in the environment to produce more useful cup dosimeters, especially for thoron , as presently used dosimeters exclude contributions from ^{212}Po[35].

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